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NASSAU RESEARCH & DEVELOPMENT ASSOCIATES Inc.
66 MAIN STREET · · MINEOLA, NEW YORK

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MILI[illegible]

Serial Number 4

FINAL DEVELOPMENT REPORT

FOR

PAINT FINISH, PREMIUM PROTECTIVE FOR WAVEGUIDES

This report covers the period between Nov. 1, 1953 to Feb. 28, 1954.

Submitted by

NASSAU RESEARCH AND DEVELOPMENT ASSOCIATES, INC.

66 Main Street
Mineola, N. Y.

To

NAVY DEPARTMENT BUREAU OF SHIPS ELECTRONICS DIVISION

On

Contract Number NObsr - 64065 Index Number NE - 111616

April 1954

Prepared by James E. McFarland

Approved by William A. Bourke

ABSTRACT

This is the final report for an investigation of the microwave attenuation and salt spray resistance of protective coatings on the inside of 1 x 1/2 brass waveguide. Sixteen finishes were tested at X-Band before salt spray, and several were found to have a very low attenuation. The loss is insignificant except at the high end of the band. The test samples were subjected to 100 hours salt spray, after which the finishes in general showed little corrosion, and there was no significant increase in attenuation.

PART I

(A) Purpose

The purpose of this contract us to investigate materials in order to determine the optimum "paint" finish for RG-69/U, RG-48/U, RG-52/U, and Navy type 14 ACM Waveguide. The investigation is primarily concerned with the finish as applied to the inside of the waveguide. Painting the inside of the waveguide will add slightly to the electrical loss; however, the attenuation remains constant over a longer period of time, and the ultimate loss is less than that for the unprotected guide. The presently used finish for the protection of the inside of wave guide is zinc-chromate primer. The finish resulting from this investigation shall be better than the zinc chromate in the following requirements.

(a) The protective finish shall protect from corrosion brass, silver plated brass, stainless steel, and silver or nickel plated stainless steel during 100 hours salt spray.

(b) The protective finish when applied to the inside of waveguide shall have the lowest possible electrical loss before and after salt spray in requirment (a). In addition to the preceding requirements the protective finish shall be capable of easy field application.

(B) Factual Data

(1) Introduction:

In accordance with the specifications of the contract, the investigation was conducted in the 8200 to 12,400 Mc. range, and the tests were made on RG-52/U waveguide, (1 x 1/2 O.D. Brass).

Electrical measurements were made at the following five frequencies: 8,200 Mc., 9300 Mc., 10,300 Mc., 11,400 Mc., and 12,400 Mc.

Each test sample consisted of a 24" straight section of RG-52/U waveguide with a UG-39/U cover flange terminating each end. The finish to be tested was coated on the inside of the sample. Comparison of the attenuation of the coated sample with that of an uncoated .. gives the attenaation contributed by the finish.

The initial part of the program was an investigation period for the purpose of selecting the finishes for test. During this period an engineer worked in conjunction with a paint consultant and various paint manufacturers with a final result of a choice of sixteen finishes. The selections were based on the past experience and claims of producers of protective coatings and producers of raw materials for protective coatings.

(2) <u>Preliminary Investigation and Selection of Finishes</u>

The following factors were considered in the selection of the finishes:

(a) Good resistance to salt spray.

(b) Low electrical loss.

(c) Easy field application - Air drying finishes not requiring baking or special techniques.

(d) Availability - Finishes should be commercially available in finished form or capable of being produced by most paint manufacturers from readily available raw materials.

The coatings include standard commercial finishes that were recommended by paint manufacturers and special formulas submitted by the paint consultant. Identification of the seventeen samples are given in Appendix A. They include the following general types:

(a) Regular phthalic anhydride alkyd resins.

(b) Phenolated Alkyd Resins.

(c) Styrinated Alkyd Resins.

(d) Vinyl Resins

(e) Epoxy Resins with Catalysts.

(f) Acrylic Resins.

Regular phthalic anhydride resins have a long period of experience in commercial production and applications. Besides the large producers of raw matefial, such as American Cyanamid Co., U.S. Industrial Chemical Co., Reichold Chemicals Inc., General Electric Co., and Sherwin Williams Co., there are many small paint companies that manufacture alkyd finishes. There is a wide range of finish possibilities. Among the factors that affect its properties are the oil length, the nature of the oil used, the phthalic anhydride content, ester-ifying agents, and the amounts and kinds of dryers. Sample No. 7 is an oil modified alkyd.

Styrinated Alkyds are alkyds modified with styrine or its derivatives. Sample No. 11 was made with the U.S. Industrial Chemicals, Inc. Arapol 880., however, other manufacturers also produce styrinated alkyds.

Bakelite Corp . is a producer of Vinyl Resins. They recommended Carroll Coatings in New Hyde Park, N. Y. asa supplier of a sampld. Carroll suggested their "Everbrite" (Sample No. 9), an Acrylic Vinyl composition which uses Bakelite's VMCH and VYHH resins. It was recommended by Bakelite that pigmentation be added to the coating for protection against ultraviolet light which would otherwise have deteriorating effect on the resin film.

A clear vinyl finish was submitted by A. C. Horn (Sample No. 17).

Samples No. 6 and No. 14 are Epoxy type resins. Epoxy resins differ from the usual types in that they set due to the action of catalysts. While the catalyst and the resin are separately stable, the mixture of the two has a limited pot life. This might be considered as a disadvantage since the mixture must be used in a limited length of time. These finishes have the advantage that once the film is formed, suceeding coats do not disolve it, thus acting as a remover; therefore, the total thickness can be easily controlled.

Sample No. 4 is a "Epon" resin which does not require a catalyst; however, it still has the characteristic of a permanent film once it is set.

The acrylic resin sample was furnished by Rohm & Hass. Sample No. 12 is their Acrylois No. B-72. Acryloid B-72 may be used as a complete film former, or combined with other film forming materials as polyvinyl copolymers, nitrocellulose, ethyl cellulose, chlorinated rubber, etc. For greater flexibility, plasticizers may be used such as bibutyl sebacate, dibutyl phthalate, chlorinated diphenyl, tricresyl phosphate, etc.

The formulas for some of the preceeding samples are known since they were made up either in our laboratory or by the producers of the raw materials. The remaining samples are private formulas of paint manufacturers, and they are not available.

(3) <u>Preparation of Test Waveguides</u>

The length of the sample guide was selected as two feet. This is short enough so that the inside of the guide can be easily coated, and as described later, the length is sufficient to give an attenuation value of an order that can be measured accurately.

Considerable consideration was given to the method for coating the inside of the waveguide, and it was decided that dipping the guide in the paint and withdrawing lengthwise at a controlled rate would give a smooth, even film. Since dipping the 2' sample would require a comparatively large amount of paint, large paint containers, and a mechanism for withdrawing the guide, a method which is equivalent to dipping was used. With the sample in a vertical position, the guide was filled with the coating material which was allowed to drain through a valve at the bottom end. By controlling the rate of drainage with the valve, the film thickness can be varied; a greater film thickness results witn a fast drainage rate.

Other factors that affect the film thickness are the solid content and drying time of the coating matetial. A greater film thickness occurs with short drying time and high solid content. A solid content of approximately 40% was recommended as optimum for dipping.

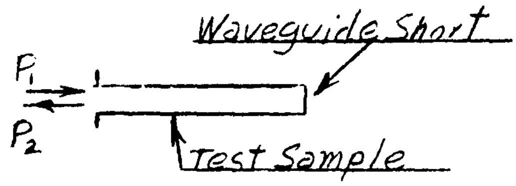
Depending on the drying time of the material, the drainage rate was between 1 and 3 inches per minute. This gave a smooth, even coat with a thickness of .0002 to .0003 inches. Several coats were applied so that a total thickness of .001 inches resulted. The total thickness was controlled in order to establish a uniform basis for comparing the electrical properties of the various finishes.

In some of the finishes, the first coat applied was disolved by successive "dippings" with a result of little film build up beyond the first coat. Samples No. 2, 8, 9, 13 and 16 showed this characteristic to the greatest degree. For these cases the finish thickness of .001 inches had to be attained by fast drainage. Even with the high drainage rate, the film was maintained smooth and even.

(4) <u>Attenuation Measurement of Samples</u>

The attenuation of the test sample was determined by measuring the ratio of the incident to reflected power at the input end of the guide with the other end terminated by a waveguide short circuit.

With reference to Fig. 1, the incident power P1 is attenuated by an amount α in traveling the length of the test sample. At the short circuit, the power in reflected and is again attenuated by α in traveling back to the input end. If the reflected power is P2 then:



$$2\alpha = 10 \log_{10} \frac{P_1}{P_2} \, db \qquad (1)$$

FIG - 1

The voltage standing wave ratio r is related to the ratio of power reflected by:

$$\frac{P_1}{P_2} = \left(\frac{r-1}{r+1}\right)^2 \qquad \text{x} \qquad (2)$$

Substituting (2) into (1)

$$\alpha = 10 \log_{10} \frac{r+1}{r-1} \, db \qquad (3)$$

Equation (3) is true if the impedance of the test sample is perfectly matched with the line which is the case since it is a straight section of waveguide.

Equation (3) assumes that there are no losses except those in the test sample; however, the attenuation measured with the test sample in place is the sum of the losses in the test sample plus the loss in the waveguide short circuit, the losses in the waveguide joints, and the losses in the impedance meter. As explained in Appendix B, these losses can be considered as an attenuation terminated by a perfect short circuit, thus they can be determined by measuring the VSWR with the waveguide short connected directly to the impedance meter. The attenuation of the test sample α is:

where

α_T = total attenuation measured with test sample connected between the impedance meter and waveguide short

α_S = attenuation measured with waveguide short connected directly to impedance meter.

in terms of the measured VSWR's ρ_T and ρ_S

$$\alpha = 10 \log_{10} \frac{\rho_T + 1}{\rho_T - 1} - 10 \log_{10} \frac{\rho_S + 1}{\rho_S - 1} \qquad (5)$$

The theoretical attenuation of a 1 x 1/2 waveguide (90/10 Bronze) varies from .05 db/ft at 8200 Mc. to .04 db/ft at 12,400 Mc. It would be expected that the actual attenuation is somewhat greater depending on the surface roughness of the inside of the waveguide. The length of the test samples was selected as two feet in order that the minimum attenuation would be of the order of 0.1 db. For 0.1 db attenuation, the VSWR to be measured is 87. Considerable error would result if a VSWR of this magnitude were measured directly by the method in which the maximum and minimum field strength in the guide is measured as a probe is moved along the line. An alternate method, which eliminates most of the inherent errors of direct measurement is described in detail in Reference 1. This method employs the shape of the standing wave pattern in the vicinity of the

REF. 1 -C.G. Montgomery, "Technique of Microwave Measurements," M.I.T. Rad. Lab Series, Vol. [illegible], Chap. 10

minimum to determine the VSWR. To apply this method it is necessary to measure the distance between points of a predetermined power level on each side of the minimum; the power level of the points is usually several times the power at the minimum. The measurement points were taken as 10 db. above the minimum in which case the VSWR is related to the distance d between points by:

$$V.S.W.R. = \frac{3\lambda_g}{\pi d} \qquad (6)$$

where the guide wavelength λ_g is in the same units as d. A detailed description of the measurement method and procedure is given in Appendix B.

(5) Results of Attenuation Measurements and Salt-Spray Tests

Before salt spray attenuation measurements were made on 16 coated samples, and for comparison the attenuation of an uncoated guide was measured. The results of these measurements are given in Table I and they are shown graphically in Fig. 2-1 through 2-17. Given in Fig. 3 is the theoretical attenuation of 1 x 1/2 O. D. (90/10 Bronze) waveguide. The measured attenuation of the uncoated guide follows the same shaped curve as the theoretical, but as expected the measured values are slightly higher; the average is approximately 22% greater. Compared to the measured uncoated guide, the attenuation of the coated sample is higher in every case. The attenuation of the coated guide is composed of the conductor losses of the uncoated sample plus the dielectric losses of the coating. Since the dielectric losses are proportional to frequency, the increase in the attenuation due to the coating is greater at the higher frequencies. The apparent best of the samples (#17) shows an attenuation increase of .001 db/ft over the band; however, this small increase is less than the accuracy of the measurements. The maximum error of the measurements is approximately plus or minus 10%, although the average accuracy should be better. Since the differences in the attenuation for several of the samples are less than the measurement accuracy, these samples can be assumed to have equally good performance. Samples 2, 3, 5, 8, 9, 11, 12, and 17, all showed increases that are about the same: within the accuracy of the measurements; the average increase is about 10% or .005 db/ft above the measured uncoated sample. The remaining samples show various degrees of higher losses up to about a 40% increase in attenuation.

After attenuation measurements, the test pieces were subjected to one hundred hours salt-spray in accordance with General Specification for Inspection of Mtl. App. II. Part G, and the attenuation was again measured at five frequencies. The measured points are plotted in Fig. 2-1 through 2-17 with the previously measured results. There is no significant increase in attenuation due to the salt spray for any of the test samples except Sample No. 1, which had no protective coating. In the case of Sample No. 1, the increase is approximately 10%.

The guides were then cut open for a visual inspection of the inside surfaces. This was necessary because the deterioration of the outside finish would not necessarily be the same as on the inside for several reasons. The thickness and application of the inside surface finish were very carefully controlled whereas the outer surface finish was applied merely for protection during salt spray and precise control was not exercised. Also, the inside surfaces were not as severely exposed during salt-spray, and the outer finish was not aged as long as the inner finish. The outer finish was not applied until after all tests prior to salt-spray were made so that handling would not damage the coating.

Every coated guide had a good inside finish after salt-spray. The conditions of the coatings are listed in Table II. Finishes described as "No Corrosion" show no sign of deterioration. The others show spots of discoloration and pitting. The spots are small and sparcely spaced, and the total area of deterioration is a small percentage of the total surface area. "Discoloration" describes a spot where the metal is discolored with the protective coating still intact. "Pitting" and "Corrosion" is a spot where the finish is broken and the metal has a pit with green corrosion products.

(C) <u>Conclusions</u>

(1) The losses due to the zinc chromate coating on the inside of 1 x 1/2 waveguide is small (of the order of .004 db/ft) where the film thickness is kept smooth and even and approximately 1 mil. thickness. Although finish No. 17 appears to have less loss than zinc chromate, the small difference is less than the accuracy of the measurements and it can be concluded that several finishes (3, 5, 8, 9, 11, 12, and 17) have about the same loss as the

zinc chromate. All of these finishes with the exception of No. 3 showed little or no corrosion after 100 hrs. salt-spray. Of the finishes just mentioned which showed attenuation comparable to zinc chromate, finishes 8, 9, 11, 12, and 17 had adhesion better than the zinc chromate.

(2) Since the losses of the dielectric film vary directly with frequency, they would be much greater at higher frequency, where in addition to the greater dielectric losses, the film thickness is a greater proportion of the waveguide dimensions. Losses for the same finish would be insignificant in guide sizes larger than 1 x 1/2 for most practical purposes.

(3) There was no noticeable change in attenuation due to 100 hours salt-spray.

PART II

RECOMMENDATIONS

1. It is recommended that the use of zinc chromate be continued for the protection of the inside of waveguide sizes larger than and including X-band. The small improvement in attenuation of some of the finishes investigated does not warrant the standardization of another paint.

2. The method for coating the inside of waveguide should be changed from that described in the "Electronic Installation Practices Manual-Rigid R.F. Transmission Lines" to the method given in this report. Pouring the paint out of the open end of the waveguide results in a thick uneven coat with loss greater than that of a coat applied by slow drainage of the paint.

3. Since the investigation described in this report indicated that losses in the various finishes become more significant in the upper frequency range for the X-band waveguide, namely in the vicinity of 12,400 megacycles, and since it is further known that this type of loss is an increasing function of frequency, it is recommended that a new investigation be initiated. This investigation should be directed toward a study of the attenuation, before and after exposure, at higher frequency in the smaller wave guide sizes. The tests to simulate exposure should be much more severe than 100 hours salt spray in order to simulate more accurately the actual conditions of use over a long period of time. Such an investigation would make use of only the finishes which appeared most feasible in the investigations described herein.

PART III

Appendix A

IDENTIFICATION OF FINISHES

Sample Number	
1.	No Finish
2.	Aircraft Zinc - Chromate primer specification MIL-P-6889A, Randolph Products Company, Carlstadt, N. J.
3.	Black, Insulating Varnish, E. I. Du Pont De Nemours & Co., # VAB-1279.
4.	Modified Epon Resin, Benjamin Moore & Co., # 74 Clear [illegible].
5.	General Electric # 1201 Red Enamel (Glyptal), reduced with G. E. # 1500 Thinner.
6.	Epoxy Resin Type, Ciba Company, Inc., Ciba KD 199 (50% solid) Catalyst 5 phr Ciba # 930 Hardener. Thinner - Cellosolve, butyl acetate, or diacetone alcohol.
7.	Oil Modified Alkyd Resin, General Electric # 1202 Clear Varnish (Glyptal), reduced for dipping with G. E. # 1500 Thinner.
8.	Prufcoat BX Gray Enamel, Prufcoat Laboratories, Inc., New York, N. Y.
9.	Carroll Products Inc., New Hyde Park, N. Y., "Everbrite", Acrylic Vinyl Composition, gray pigmentation.
10.	Phenolated Alkyd, Reichold Chemicals, Inc., Elizabeth, N. J.

Solid 40%	Solvent 60%
90% P531 Beckosol	Solvesso - 100 100%
10% 1338 Beckosol	
100%	

Dryers added - 0.4% lead in form of lead naphthenate
0.04% cobalt in form of cobalt naphthenate based on solid resin content.

Appendix A

IDENTIFICATION OF FINISHES
(cont.)

Sample Number

11. Styrinated Alkyd, U. S. Industrial Chemical, Inc.

Solids 40%	Solvent 60%
U. S. I. Aropol 880	Xylene Solvesso 100

Dryer added - .04% cobalt, based on solid resin content.

12. Acrylic Resin, Rohm and Haas Co., Philadelphia, Pa.

Solids 40%	Solvent 60%
Acryloid B-72	Toluene

13. Gloss White Air Dry Dip # 2-7593 Vinyl Type, Randolph Products Co., Carlstadt, N. J.

14. Epoxy Resin Type, Shell Chemical Corp. Formulation

Solids 60%		Solvent 40%	
Epon 1001	97%	Methyl Isobutyl Ketone	33.3%
Beetle 216-8	03%	"Cellosolve"	33.3%
	100%	Xylene	33.4%
			100.0%

Catalyst, 6 phr diethylene triamine based on Epon resin solids.

15. "Corrosite" coating, Reliance Paint Co., Inc., Brooklyn, N.Y.

Three coat system:
- Coat 1 - 4 parts Corrosite # 44 Primer mixed with 1 part Corrosite #44 Primer Thinner Catalyst.
- Coat 2 - Corrosite # 44 Tiecoat
- Coat 3 - Corrosite # 22 Top Coat

16. Clear Air-Dry Dip # Z-7592, Vinyl Type, Randolph Products Co., Carlstadt, N. J.

17. Clear Vinyl, #PFD-2422, A. C. Horn Co., L. I. City, N. Y.

Appendix B

DESCRIPTION OF MEASUREMENT METHOD

A diagram of the measurement set-up is shown in Fig. 4. The voltage standing wave ratio looking into the test sample is determined by measuring the travel of the impedance meter between power points 10 db. above the minimum of the standing wave in the line. A precision 10 db. microwave attenuator is used as a reference to determine the 10 db. points, in which case a constant power level is maintained into the crystal mixer, thus eliminating errors due to the response characteristics of the mixer and the receiver. Buffer pads are located before and after the precision attenuator which serve to provide a matched line on each side of the precision attenuator and also isolate the klystron to prevent "pulling" as the precision attenuator is changed. The signal is CW of frequency f_1. The L. O. signal is tuned to a frequency f_2 which is 30 Mc. from f_1, and the 30 Mc. output of the mixer is detected by a 30 Mc. receiver.

With the test sample in the line as shown in Fig. 4, the VSWR is measured. The calculated attenuation from the measured VSWR is the loss in the test sample plus other losses that might occur, such as the loss in an imperfect waveguide short circuit, the loss in the short section of line in the impedance meter between the probe and the input flange of the test section, and losses in the flange joints. The loss in the waveguide joint between the test sample and the waveguide short was essentially eliminated by positioning the short $\lambda_g/4$ from the joint which places a current minimum at the joint. Loss in the joint between the Impedance Meter and the test sample was checked experimentally. The adjustable short was moved so that a current maximum and minimum alternately appeared at the joint, and no appreciable change was noted in the depth of the standing wave minimum indicating that the joint had negligible loss. The remaining losses that might cause error were measured with the test sample removed from the line and the adjustable short connected directly to the Impedance Meter. The losses to be measured can be considered as an attenuator terminated by a perfect short. This attenuation is measured in the same manner as the attenuation of the test sample.

The attenuation of the test sample is:

$$\alpha = \alpha_T - \alpha_S$$

where α_T is the attenuation measured with the test sample in place and α_S is the attenuation measured with the waveguide short connected directly to the Impedance Meter.

Possible errors in the measurements can be attributed to several sources, one of which is the accuracy to which the 10 db. power points are set. The calibrated attenuator used has an accuracy of plus or minus 0.2 db. including the setability at the 10 db. point. Power variations in the signal source and variations in the receiver response were estimated at approximately plus or minus 0.1 db., and the setability of the power level at the 10 db. points was approximately plus or minus 0.2 db; this latter error was partly caused by the setability of the drive mechanism on the impedance meter and partly the setability of the indicator on the receiver. The total error of setting the 10 db. points is plus or minus 0.5 db. which would cause a maximum error of approximately 6% if all the errors added in the same direction for both points which is unlikely. The second source of error is in the measurement of the displacement between the 10 db. points. The longest distance measured was accurate to approximately plus or minus 1.0% resulting in an attenuation error of approximately 1.0%. Attenuation measurement of the short circuit connected directly to the Impedance Meter was possibly in error plus or minus 10% because of error in measuring the displacement and 10 db. points. This would result in an error of about plus or minus 1.5% of the attenuation of the test sample.

Other small errors such as frequency modulation of the klystron, errors in λ_g due to tolerances in frequency and dimensions of the Impedance Meter, and error in EQUA.6, probably bring the total error in the attenuation measurement to approximately plus or minus 10%.

TABLE I

MEASURED ATTENUATION OF TEST PIECES

Sample No.		Frequency	(Mc.)			
		8200	9300	10300	11400	12400
1	α_1	.069	.060	.059	.047	.052
	α_2	.075	.065	.066	.055	.056
2	α_1	.072	.061	.063	.059	.058
	α_2	.071	.062	.065	.056	.058
3	α_1	.073	.064	.071	.057	.059
	α_2	.076	.062	.069	.056	.060
4	α_1	.090	.083	.078	.076	.076
	α_2	.091	.081	.080	.075	.075
5	α_1	.077	.064	.062	.055	.059
	α_2	.076	.064	.063	.056	.058
6	α_1	.080	.066	.069	.065	.066
	α_2	.082	.068	.070	.063	.068
7	α_1	.075	.072	064	.060	.063
	α_2	.073	.070	071	.058	.058
8	α_1	.070	.063	.063	.057	.058
	α_2	.071	.064	.063	.055	.056
9	α_1	.073	.063	.062	.056	.056
	α_2	.071	.065	.060	.055	.057
10	α_1	.081	.074	.072	.065	.070
	α_2	.084	.073	.072	.067	.068
11	α_1	.078	.061	.063	.055	.057
	α_2	.076	.063	.065	.056	.058
12	α_1	.078	.065	.065	.058	060
	α_2	.076	.071	.066	.056	.058
13	α_1	.079	.073	.070	.067	.069
	α_2	.079	.074	.070	.067	.066
14	α_1	.079	.072	.070	.066	.070
	α_2	.082	.072	.071	.067	.068
15	α_1	.082	.070	.070	.065	.068
	α_2	.080	.072	.072	.063	.066
16	α_1	.078	.073	.069	.062	.064
	α_2	.080	.069	.071	.063	.065
17	α_1	.075	.061	.059	.054	.051
	α_2	.073	.064	.060	.051	.055

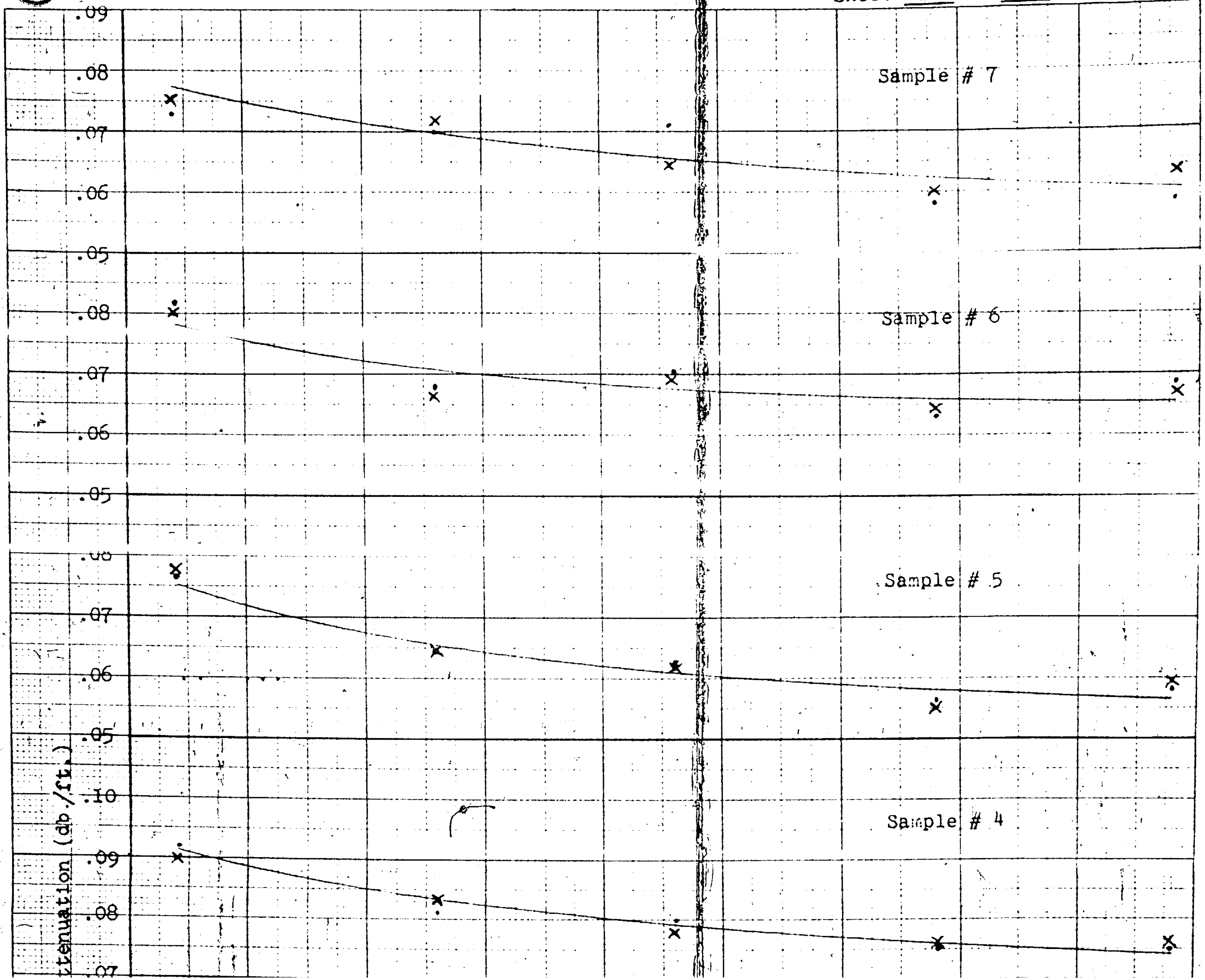
Code: α_1 - Attenuation before Salt Spray db/ft
α_2 - Attenuation after Salt Spray db/ft

TABLE II

INNER SURFACE INSPECTION AFTER SALT SPRAY

Sample Number	
1.	Severe pitting and discoloration on two walls - one narrow wall and one broad wall partially corroded.
2.	No corrosion.
3.	Spots of green corrosion on one narrow wall and two corners.
4.	Spots of green corrosion in two corners.
5.	No corrosion.
6.	Spots of pitting and discoloration on one narrow wall and one broad wall.
7.	Discoloration at ends of guide, few spots of corrosion in one corner.
8.	No corrosion.
9.	No corrosion.
10.	No corrosion.
11.	Spots of discoloration in two corners.
12.	Spots of discoloration on one narrow wall and one broad wall.
13.	Spots of discoloration under film (not visible through white pigmented coating.)
14.	Spots of discoloration and green corrosion in two corners.
15.	No corrosion.
16.	Several small spots of discoloration on one narrow wall.
17.	Several small spots of discoloration.

Sheet 1 of 3 sheets



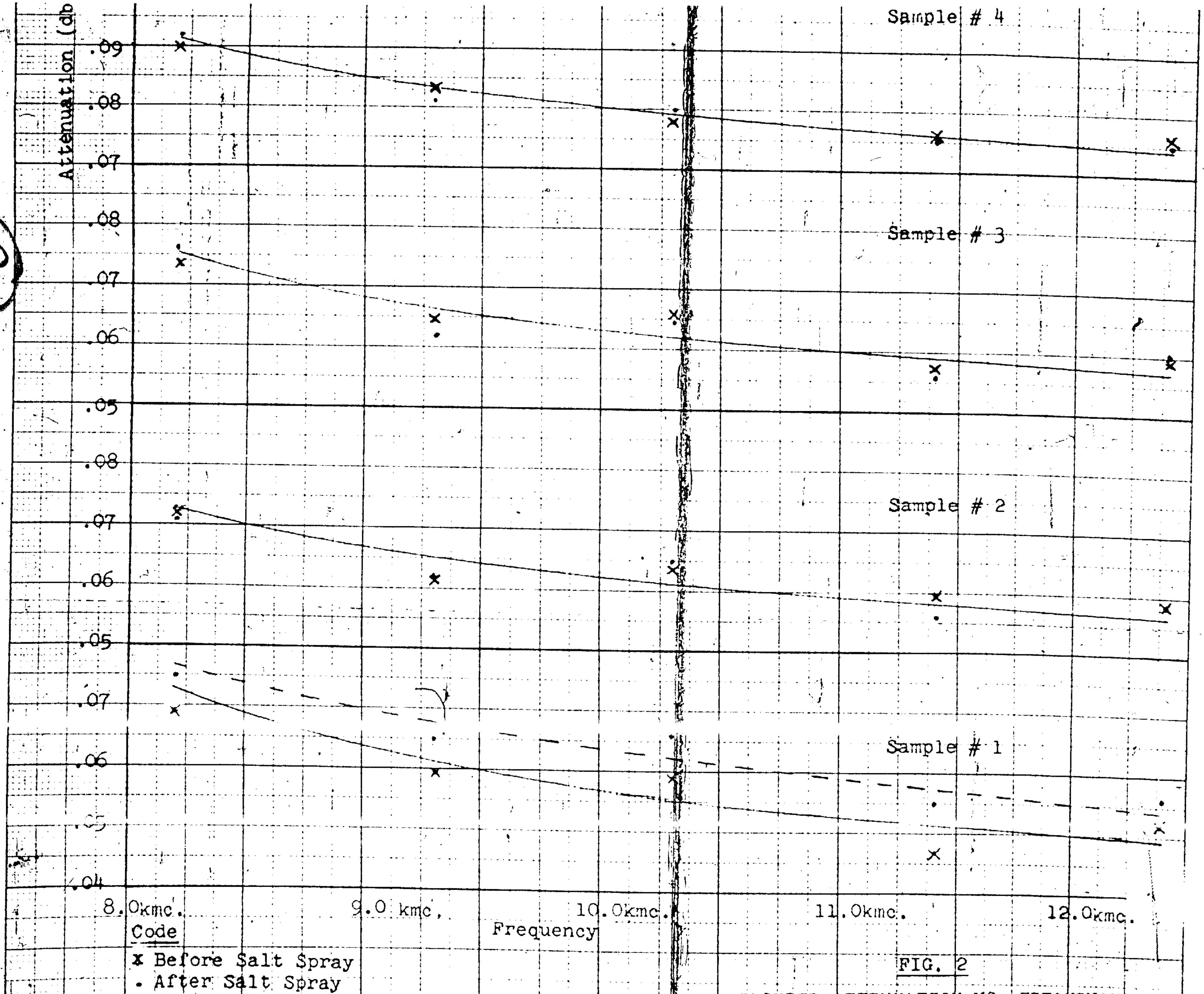
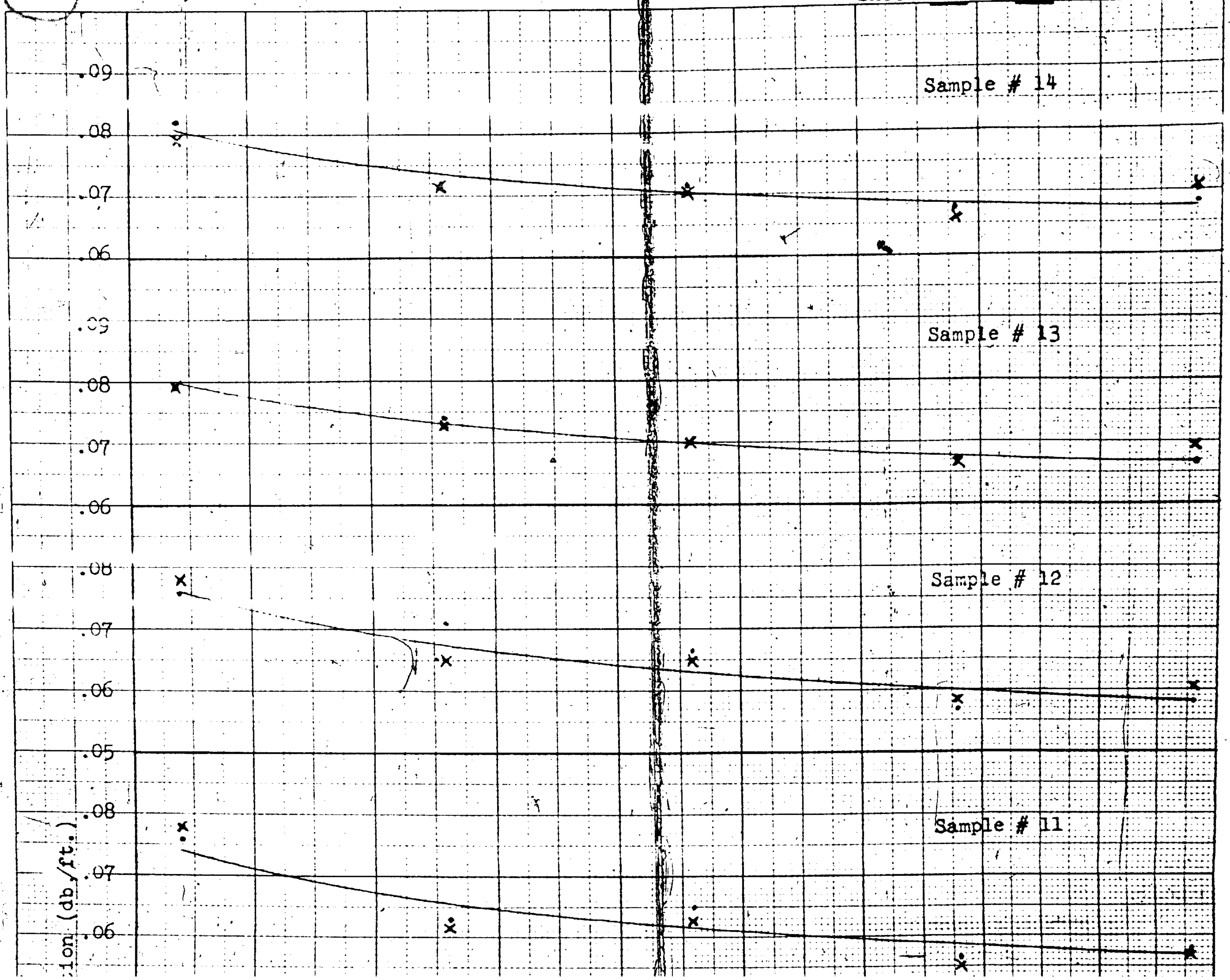


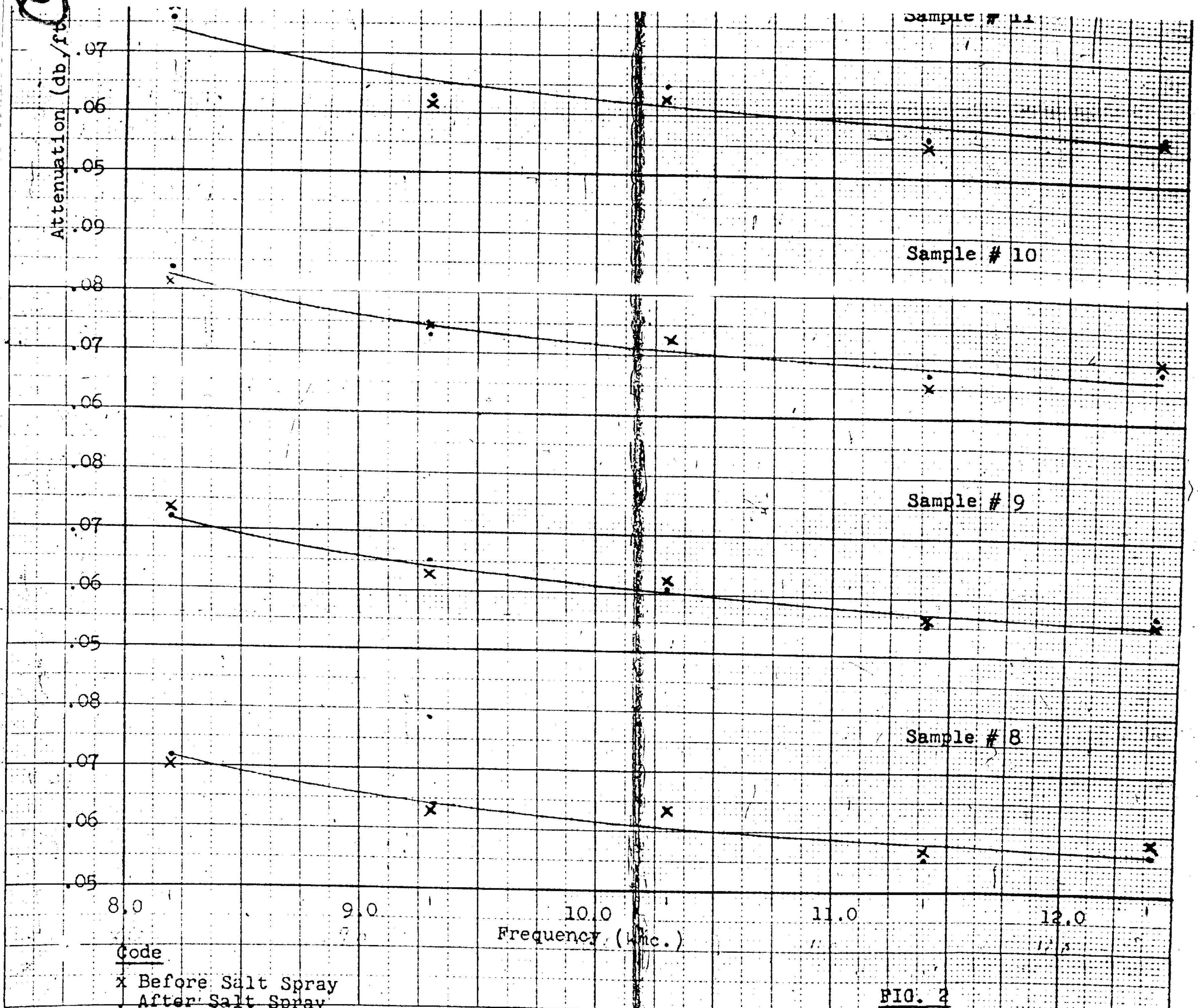
FIG. 2

MEASURED ATTENUATION VS. FREQUENCY
FOR WAVEGUIDE TEST PIECES

NO. 3400-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH

EUGENE DIETZGEN CO.





Sample # 11
Sample # 10
Sample # 9
Sample # 8
Attenuation (db/ft)
.07
.06
.05
.09
.08
.07
.06
.08
.07
.06
.05
.08
.07
.06
.05
8.0
9.0
10.0
11.0
12.0
Frequency (kmc.)
Code
x Before Salt Spray
• After Salt Spray

FIG. 2

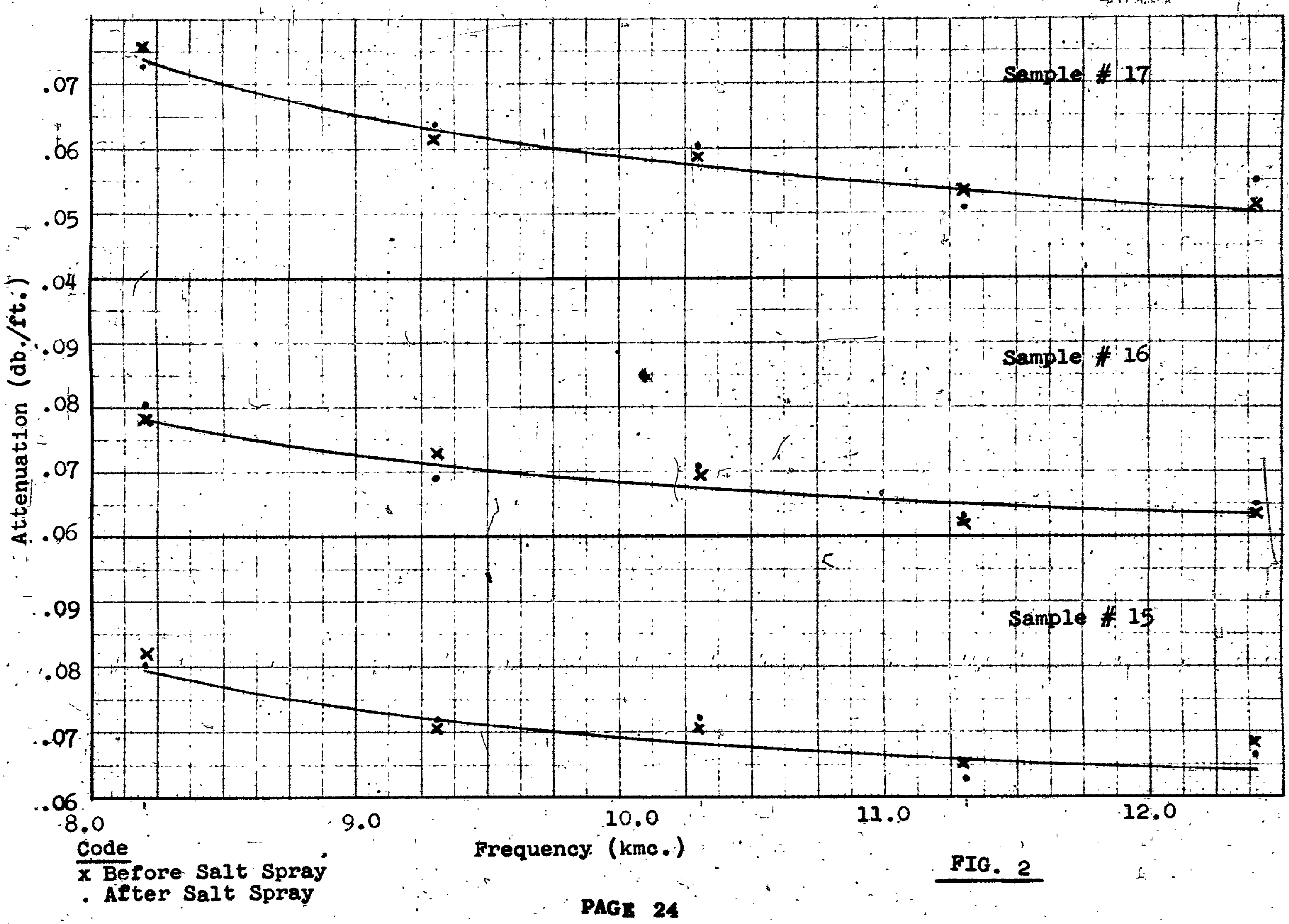

Sample # 17
Sample # 16
Sample # 15
.07
.06
.05
.04
.09
.08
.07
.06
.09
.08
.07
.06
Attenuation (db./ft.)
8.0
9.0
10.0
11.0
12.0
Frequency (kmc.)
Code
x Before Salt Spray
. After Salt Spray

FIG. 2

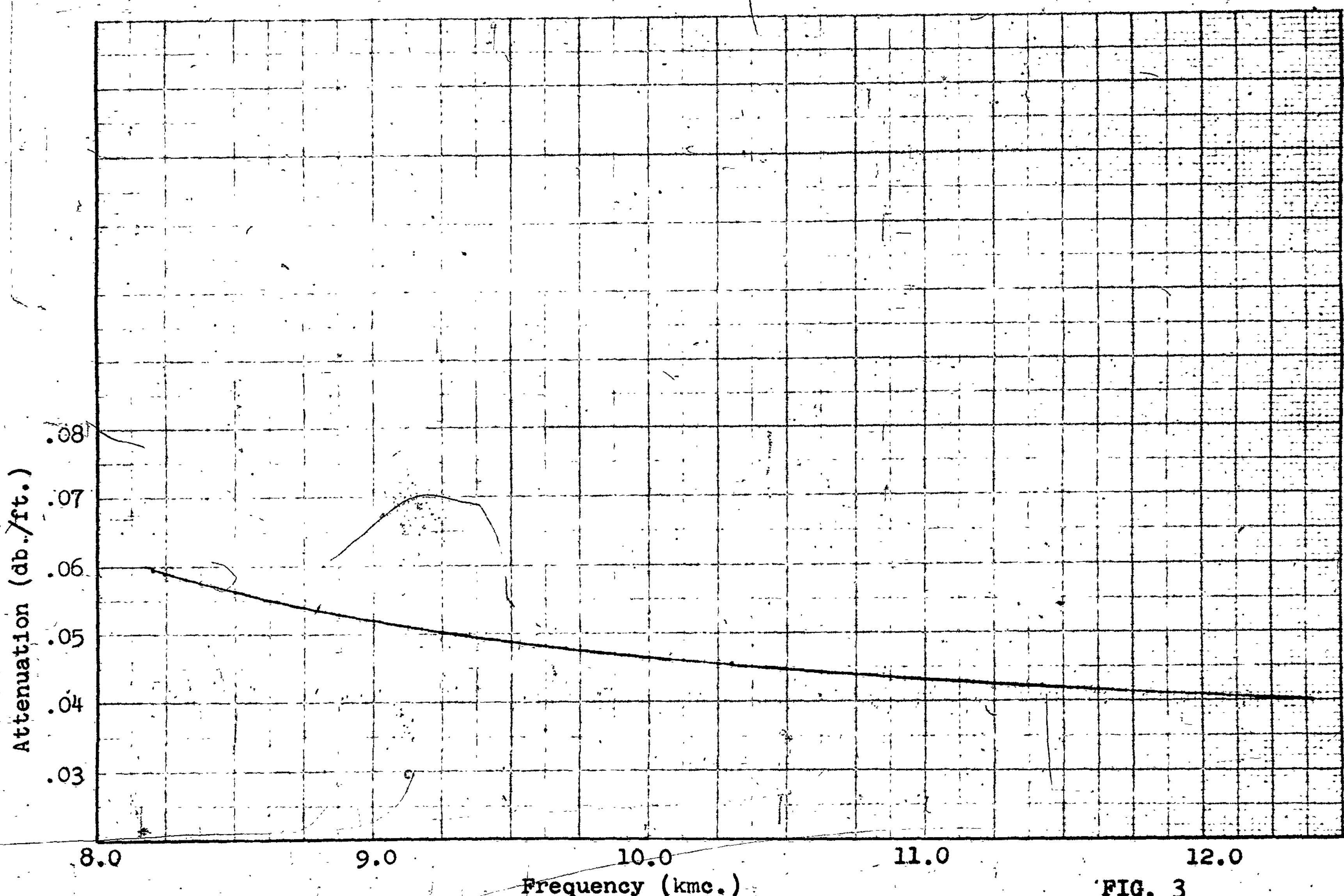


FIG. 3
THEORETICAL ATTENUATION OF 90/10 BRONZE
WAVEGUIDE - 1 x 1/2 O.D. x .050 WALL

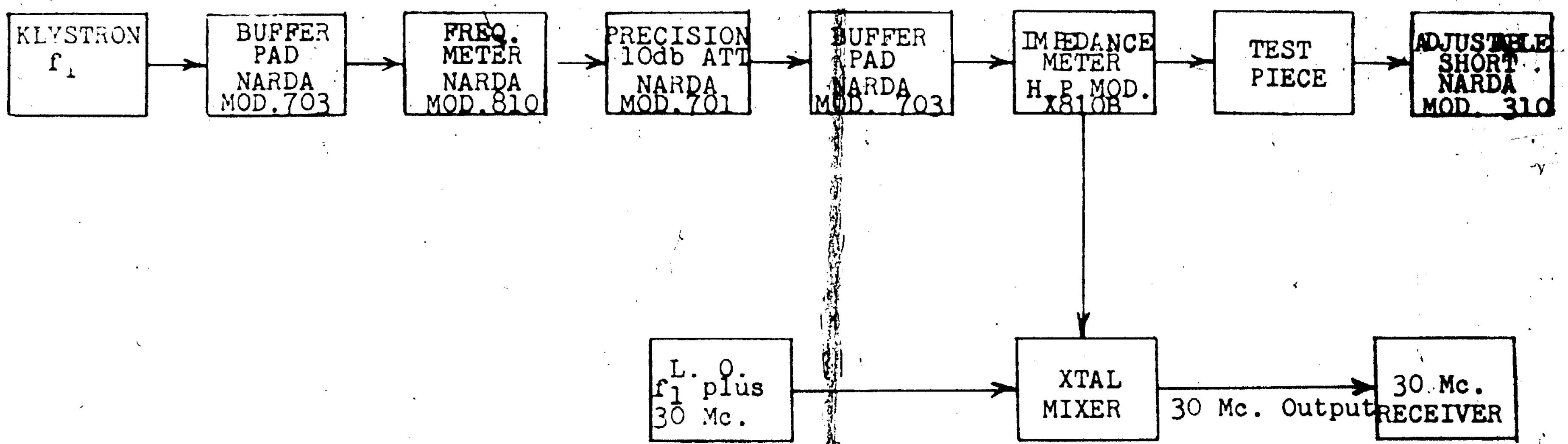


Fig. 4

SETUP USED FOR ATTENUATION MEASUREMENTS